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TECHNICAL REPORT
NATICK/TR-96/030

AD______________

SOLDIER SYSTEM ARCHITECTURE (SSA) MULTIPLE CRITERIA DECISION AID DETAILED DEVELOPMENT PLAN

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At present there are a variety of computer modeling tools designed to assist the military analyst. However, these models are cumbersome to use and require a high degree of operator expertise, significant investment in input parameter preparation and skilled analysts to interpret the results. Furthermore, the models do not allow the addition of novel threats, and they do not consider changes in performance or capabilities resulting from changes in technology. Also, these models are not structured to consider risk, cost and time to field for any anticipated changes in the input parameters. In essence, they are not structured to answer resource allocation questions. To both resolve the equipment questions and optimize the development of the Soldier System, a Soldier System Architecture (SSA) Multicriterial Decision Aid (MCDA) is being developed. The SSA will consist of two modules. The first will quantify the changes to soldier capabilities from changes in the items, equipment or technologies available to the Soldier System. The second will assist in the determination of optimal resource allocations based on trade-offs.

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PREFACE

This research was sponsored by the U.S. Army Natick Research, Development and Engineering Center, Advanced Concepts Division, Advanced Systems Concepts Directorate, Natick, MA. The contract number was DAAK60-93-K-0001, under the Broad Agency Announcement Solicitation. Mr. John A. O'Keefe was the technical manager and Mrs. Elaine Scarnici was the contracts specialist for the effort.

SOLDIER SYSTEM ARCHITECTURE
(SSA)
MULTIPLE CRITERIA DECISION AID
DETAILED DEVELOPMENT PLAN

SECTION 1
INTRODUCTION

1.1 BACKGROUND

U.S. Army programs concerned with the development and fielding of new equipment must support increasingly complex mission requirements and allow the soldier to successfully operate in increasingly hostile and sophisticated threat environments. Resources are highly constrained and are under constant scrutiny. Consequently, new programs and equipment must be cost-effective and must be capable of apriori demonstration of the fact. Additionally, the individual soldier is already burdened with an excessive load. Therefore, new equipment must not increase the soldier's load while maintaining or increasing his mission capabilities.

At present, there are a variety of computer modeling tools designed to assist the military analyst, but none that address the needs of the Soldier as a System. Additionally, these models are cumbersome to use and require a high degree of operator expertise, significant investment in input parameter preparation, and skilled analysts to interpret the results. Furthermore, they do not allow the addition of novel threats nor do they consider changes in performance or capabilities resulting from changes in technology. None of these existing models consider performance, nor are they structured to consider risk, cost, or developmental time. In essence, they are not structured to answer resource allocation questions.

To both resolve the equipment questions and optimize the development of the Soldier System, the Soldier System Architecture (SSA) was proposed by Natick Research, Development and Engineering Center (Natick). This SSA will provide an analytical and quantifiable methodology to resolve resource allocation questions while viewing the soldier as a system.

Natick is currently conducting the Soldier System Hierarchical Effectiveness Model to address the immediate, time-sensitive needs of Soldier System initiatives. However, Natick believes that an additional independent assessment of the over-all technical approach is needed to ensure that the final SSA product will meet the more challenging needs of the future. To accomplish this, an SSA multi-criteria decision aid (MCDA) is being developed which meets the broader needs of the future. This SSA MCDA will consist of two modules. The first will

quantify the changes to soldier capabilities given changes in the items, equipment, or technologies available to the Soldier System. The second will assist in the determination of optimal resource allocations based on the trade-offs between costs, technological risks, and benefits, as restricted by the availability of funds, time, and personnel resources. Prior to initiating development of the MCDA, Natick conducted a literature search of appropriate methodologies followed by a market survey of applicable software products which utilize the methodologies discovered in the literature search. SAIC was contracted to perform these studies which will serve as the first phase of the SSA MCDA development.

To date, SAIC has completed:

- A detailed literature search to identify past or present Department of Defense (DoD), Academia and/or Industry methodologies that factor performance and resource allocation into final output.
- A market survey of applicable software products implementing such methodologies.
- A User Conference to solicit inputs and needs for such a MCDA from potential users.

1.2 PURPOSE

The purpose of this report is to document the detailed plan for the development of the SSA MCDA based on the results of the earlier efforts in this initial phase.

1.3 SCOPE

The plan for the SSA MCDA encompasses:

- Determination of host software based on the methodology and software assessment work completed in Phase I of the SSA.
- Development of a baseline soldier entailing detailed definitions and descriptions of the current Soldier System.
- Development of data tables which will serve as uniform formats in the collection of data used in the MCDA.
- Development of a prototype of the MCDA which will serve as a proof of principle before the dedication of resources for the full model development. This prototype will model both Module I and II of the MCDA.

- Review of the prototype prior to full model development to assess developmental risk.
- Development of a full operating system of the SSA MCDA Module I and II incorporating the information gained through the prototype process.
- Testing of the MCDA based on developed alternatives for acceptance as a valid decision tool.
- Training of potential users.
- Documentation of the model in the form of a user's manual and tutorial of the SSA MCDA decision tool.

SECTION 2
SOFTWARE DEVELOPMENT APPROACH

The SSA MCDA will be used as a decision tool to evaluate candidate material and technologies being considered to improve the Soldier System. The methodology to develop the SSA MCDA is based on classical information systems design criteria tailored to the specific requirements of the Soldier System. The development of the SSA MCDA will take approximately one year and consist of the following tasks:

- Software requirements definition stage
- Software determination stage
- Prototype design stage
- Program Review
- Full Model design stage
- Test stage
- Training and implementation stage

Figure 2.1 illustrates graphically the time-line of the SSA MCDA development.

2.1 SOFTWARE REQUIREMENTS DEFINITION STAGE

The contractor will, based on the three reports compiled for Phase I and any additional information provided by Natick, finalize the software requirements for the SSA MCDA. The SSA MCDA must satisfy the following requirements:

- Be capable of operation on a personal computer (PC), for performance reasons it is recommended to run on a 386/33 or higher.
- Be capable of quantifying increases in Soldier System effectiveness based on new technologies and equipment.
- Be capable of making a selection or trade-off between alternatives based on explicit, well defined attributes of those alternatives. This model will not be designing the Soldier System to reach a desired goal of effectiveness, but evaluating finite numbers of alternatives to measure increases or decreases in overall Soldier System effectiveness.
- Incorporate the work done in the Soldier Integrated Protection Ensemble (SIPE) effort.

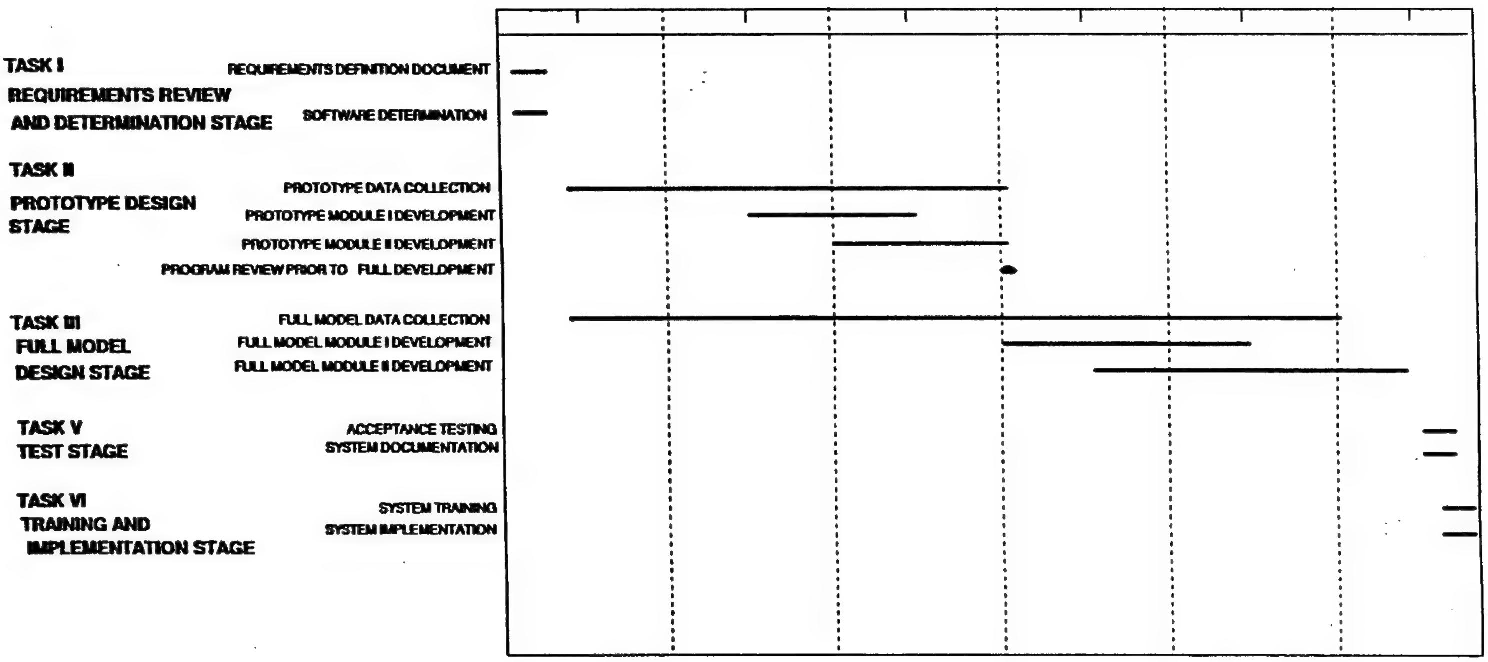

Figure 2.1 SSA MCDA Overall Time-Line.

2.2 SOFTWARE DETERMINATION STAGE

Based on the work done in Task I of the SSA MCDA development, the contractor will conduct a final software determination which will decide the type of modeling tool or tools to be used in the development of the SSA MCDA. At this time any further information or requirements that were developed since the completion of Task I will be integrated into this decision. The contractor will select a type of modeling software which utilizes a Multi-Attribute Decision Methodology (MADM) that, from the methodology assessment done in Phase I, was judged the optimal methodology by which to accomplish the goals of the MCDA. The MADM includes such analytical techniques as Decision Trees and Influence Diagrams which trade-off and evaluate alternatives with uncertain outcomes.

Decision Trees offer an optimal solution by deriving the best choice from a series of decisions under uncertainty or risk. A Decision Tree is a graphical representation of the decisions, uncertainties and values of a problem, and a framework for numerical evaluation. Based on the principals of dynamic programming, the solution of a Decision Tree starts at the tree endpoints and computes the expected value at each uncertainty node and the optimal value at each decision node. The sub optimal choices at each decision node are dropped and the roll back continues until the first node of the tree is reached. The optimal solution is derived by the choices selected at each decision node that maximize the value of the objective function. Being a graphical representation of the problem, Decision Trees makes the linkage between decisions and the state of information discernible to the functional users.

Influence Diagrams are a relatively new technique for gathering expert opinion and knowledge. Influence Diagrams were developed as a Bayesian computer-aided modeling tool by Howard and Matheson. An algorithm for solving Bayesian decision analysis problems through Influence Diagram manipulations was constructed by Shachter. Influence Diagrams are a graphical approach to assessing system dynamics and interrelationships while attempting to capture expert opinion on preference between attributes. There is potential benefit from this type of approach in assessing the interrelationships of the SSA MCDA capabilities. The SSA problem in its definition is inherently interdependent. For example, the ultimate utility of both micro-climate cooling and the soldier computer are constrained by the rate of development of power technologies. Influence Diagrams offer a methodological approach for the subject matter expert to systematically analyze the interdependencies between the SSA attributes.

The contractor will use as the basis for their selection the SSA Literature Search and Market Survey (presented in Appendix A) conducted in Phase 1, Task I. From this study the contractor will, in conjunction with Natick, make a final selection from the modeling software recommended for the SSA MCDA in the Conclusions and Recommendation section of the literature search report. A graphical representation of the previous stages is presented in Figure 2.2 with its relation to the overall timetable of the project.

2.3 DEVELOPMENT OF DATA TABLES AND STRUCTURES

The SSA MCDA, depicted in Figure 2.3 will be a multi-tiered system with each tier utilizing the output from the previous level. This analytical hierarchy which is independent of the type of software selected during the previous stages forms a "pyramid of data" leading to the overall effectiveness of the soldier system. Therefore prior to any further discussion of the plan, these major items of data and evaluation must be discussed. The objective of the SSA is to determine the overall Soldier System effectiveness. This decision will be based on three criteria: Operational Effectiveness, Cost, and Risk. The Operational Effectiveness will be derived from optimizing the five capabilities (i.e., Lethality, C&C, etc ...) of the Soldier System which were developed in the Soldier Modernization Plan and Soldier Performance Model. These capabilities will be described and quantified by measures of effectiveness such as "Rate of Fire", which will be given values based upon the attributes of the material or technology being studied. One of the main goals of the SSA MCDA is to discover the technologies or fields of research which will enhance the capabilities of the Soldier System. However, before analysis, these materials or technologies must be described in attributes which can be assimilated into the model. These attributes will generate the measures of effectiveness data necessary to assess their effect on to the five overall capabilities. When combined with the estimated cost and risk factors of the equipment being assessed, the MCDA will yield the material or technology which will optimize the Soldier System overall effectiveness.

Phase I identified data collection of the measures of effectiveness as the critical issue in the development of the SSA MCDA. If the data within the model are questioned, then the data coming out of the model in the form of results will be questioned. To minimize this problem area, the contractor will develop a uniform format of data tables which will serve as the baseline for the data collection stage of the MCDA development. These data tables will ensure that all the attributes and alternatives will be evaluated on the most "level playing field" possible. The data tables will outline and define the measures of effectiveness that will be used to evaluate the alternative technologies and equipment in the MCDA. These tables will be developed by the contractor and approved by Natick ensuring that any previous or concurrent data collection

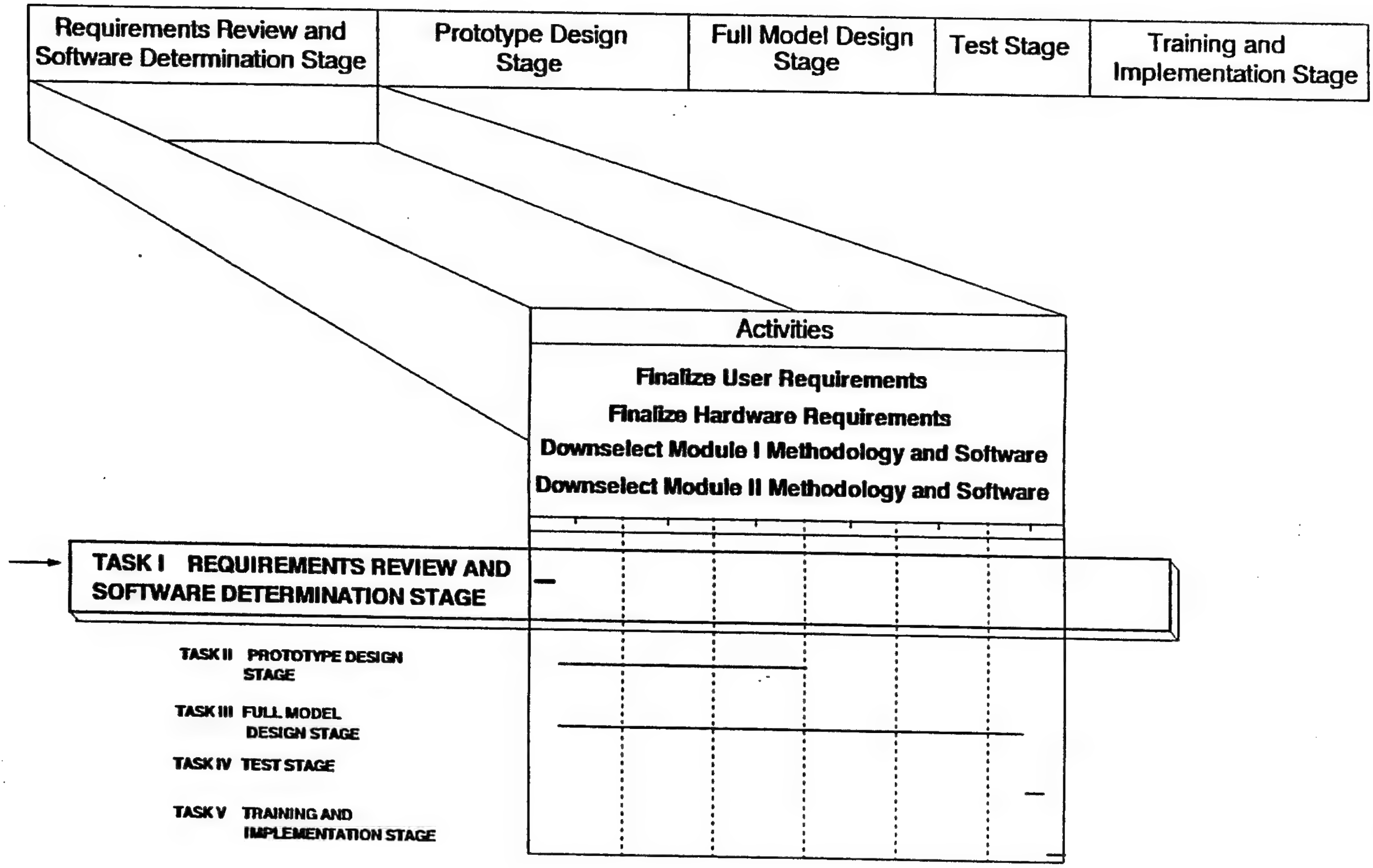

Figure 2.2 Requirements Definition and Software Determination Stage.

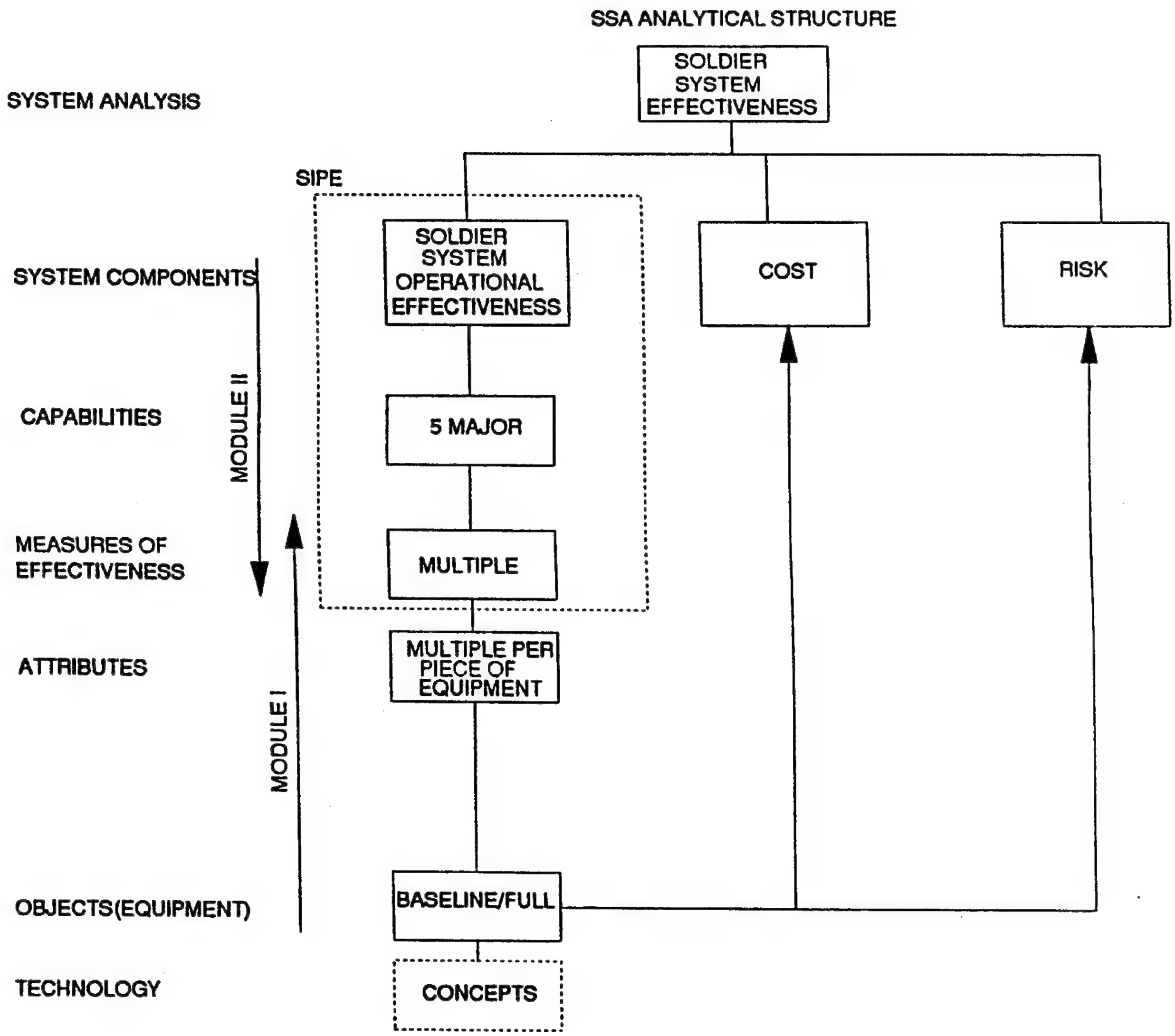

Figure 2.3 SSA Analytical Structure.

efforts are included in the design of the data tables.

As part of this process, the contractor shall conduct a baseline definition exercise in order to properly describe and define the current Soldier System. This description will portray in detail all equipment and material composing the current Soldier System. The description and data supporting these will be based on the capabilities and measures of effectiveness discussed earlier. This will be done in an effort to gather information which can be used to accurately measure the impact on overall effectiveness. Once this baseline is established and approved by Natick, the contractor will identify potential data sources and plan any appropriate trips or interviews to retrieve the necessary data.

2.4 PROTOTYPE DESIGN STAGE

For the first stage of the MCDA model development, the contractor will design a prototype model to serve as a proof of principle of the methodology and software approach. A piece of equipment, with two versions, utilized by the Soldier System will be selected to represent the tasks needed to develop a decision tool of the entire Soldier System. The steps taken to develop this prototype will be tracked and evaluated at completion to review how the approach could be changed to enhance the remaining model development effort.

2.4.1 PROTOTYPE DATA COLLECTION

Using the data tables and data sources developed earlier, the contractor will gather data for the prototype MCDA. This data collection constitutes gathering attribute and measures of effectiveness (MOE) data, as appropriate, on the pieces of equipment selected. The contractor will conduct the research through various means to include: DoD standard documents, government information activities and databases, site visits, reference material research and extraction, and any other designated public or private information sources. All data collection efforts will be conducted in conjunction with Natick to ensure that the proper sources of data are being contacted and that useful data is being obtained.

2.4.2 PROTOTYPE MODULE I DEVELOPMENT

As mentioned earlier, the SSA MCDA will be divided into two modules with the first quantifying the capabilities of the Soldier System. As the attributes and MOE will cover a wide variety of units of measure, the contractor shall employ Utility Theory to provide a means of capturing subjective expressions of worth in numeric form. Utility Theory arises from the classical precepts of rationality, preferential maximization, and predictability of aggregate

phenomena. Utility Theory is prescriptive, concerned with the choice among pre-specified alternatives according to the principle of maximization of subjective expected utility. This theory is drawn from statistical decision theory, game theory, mathematical economics, and econometrics. Utility Theory is driven by utility functions or curves. In this study, each utility curve will correspond to a specific measure of effectiveness of the Soldier System. These utility curves will allow for changes within a capability without losing relative worth. Once the measures of effectiveness are all converted into a util, (the units of measure on a utility curve) all the alternatives can be measured on a common scale eliminating the problem of comparing "apples and oranges". Utility functions will be developed by the contractor for each measure of effectiveness of the Soldier System. These curves will be approved by subject matter experts, selected by Natick, as accurate representations of Soldier System utilities.

2.4.3 PROTOTYPE MODULE II DEVELOPMENT

The contractor will develop the SSA MCDA Module II which will determine the optimal resource allocations based on the trade-offs between costs, technological risks, and benefits; as restricted by the availability of funds, time, and personnel resources. The prototype of this module will be built upon the previous data collection and Module I efforts. It will assess a trade-off between the two pieces of equipment developed in Module I and optimally allocate resources based on cost, risk and operational performance. The modeling software to accomplish this will be determined in the software determination phase. Figure 2.4 illustrates the prototype design stage and its relationship to the overall time-line of the project.

2.5 PROGRAM REVIEW PRIOR TO FULL DEVELOPMENT

Once the prototype modules are developed and tested, a program review will be conducted to assess the value added of the system and the developmental risk. Further development of the system will rest on Government approval to continue the full system development.

2.6 FULL MODEL DESIGN STAGE

Following the program review and government approval of the prototype design, work will begin on the full model. The development stages of the full system correspond to those used in the prototype effort, but the work takes on greater breadth in many of the stages as research is carried on across several areas (weapons, uniforms, etc) in parallel.

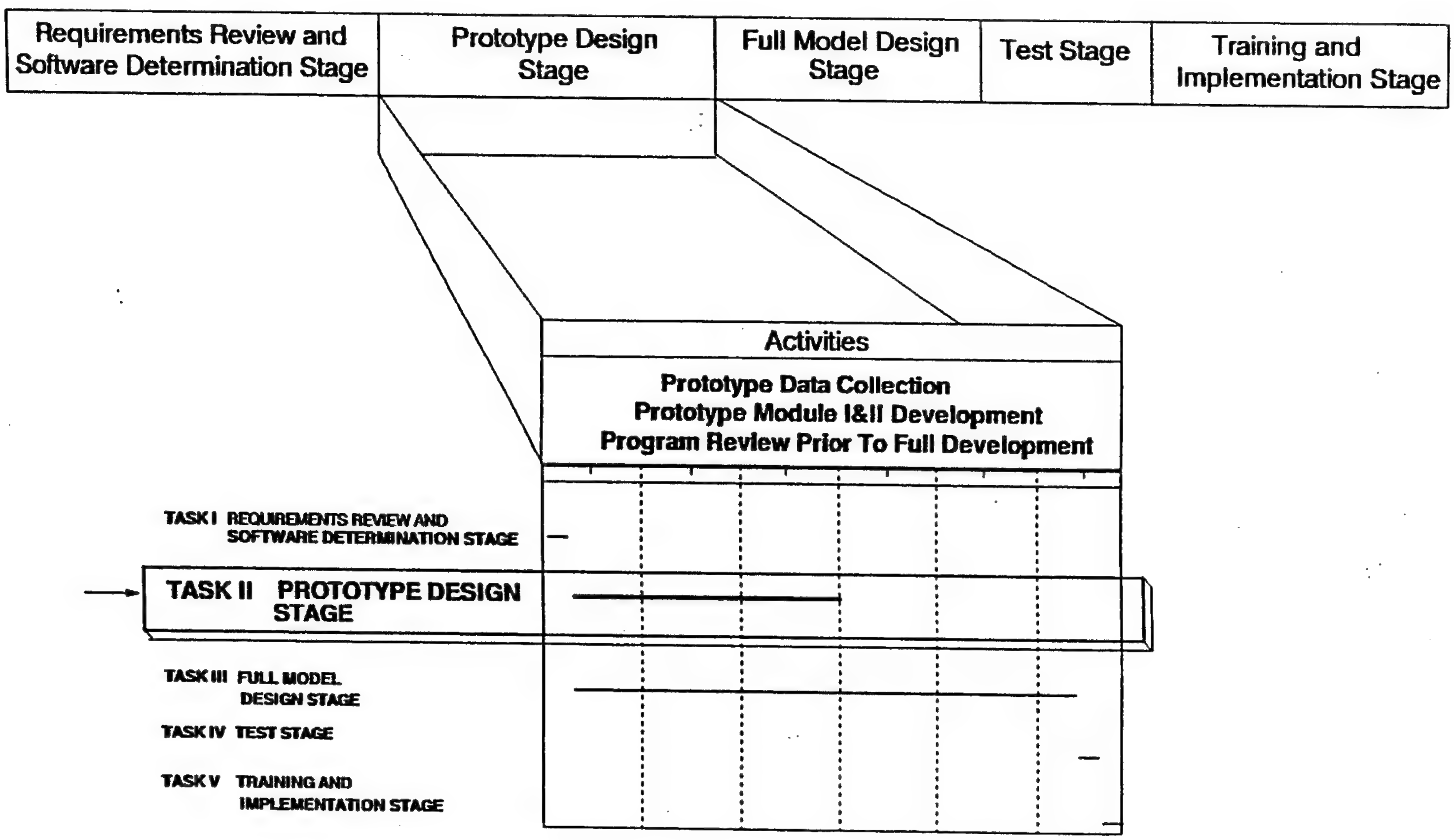

Figure 2.4 Prototype Model Development Stage.

2.6.1 FULL MODEL DATA COLLECTION

Data collection will be one of the major efforts in the design of the full model. Although some data will have been collected during the prototype development, the vast majority of the information required for the full system will have to be collected during this phase. In order to accomplish this in the time allotted, multiple data collection teams will have to be employed to gather the required information. Although much of the required data will be extracted from previous reports and studies, it is anticipated that these teams will have to rely extensively on visits to subject matter experts throughout the Army Research Laboratory and other organizations to gain insight and the latest information on each piece of equipment. Although these teams will operate independently, data will be stored in a single repository facilitating the ongoing development of the MCDA.

2.6.2 FULL MODEL MODULE I AND MODULE II DEVELOPMENT

Development of Modules I and II of the full model will begin as soon as data becomes available from the data collection phase. The development of the individual utility curves will be conducted in parallel, as they are mutually exclusive of each other. The development of the utility curves for Module I will require intense interaction between the contractor and the study proponent and subject matter experts to verify their validity.

The development of the interactions in Module II will require an equally intense coordination effort. Module II will be built by starting with the prototype model and adding new pieces of equipment and the corresponding relationships in individual segments thereby confirming the operation of the Module as each new section is added. This prototyping concept will ensure that the SSA model remains fully functional as it evolves from the prototype stage to the full SSA maturity. Building the system using influence diagrams should also prove to be extremely beneficial in explaining to subject matter experts the various interactions and relationships as they are developed. For the full model development, all the pieces of equipment and material utilized by the baseline soldier will be coded into the model.

A limited number of alternative technologies or pieces of equipment will be developed to demonstrate and test the model. These pieces of equipment will be selected so each capability of the Soldier System will be implemented in the evaluation. The time-line for the development of the full model is presented in Figure 2.5.

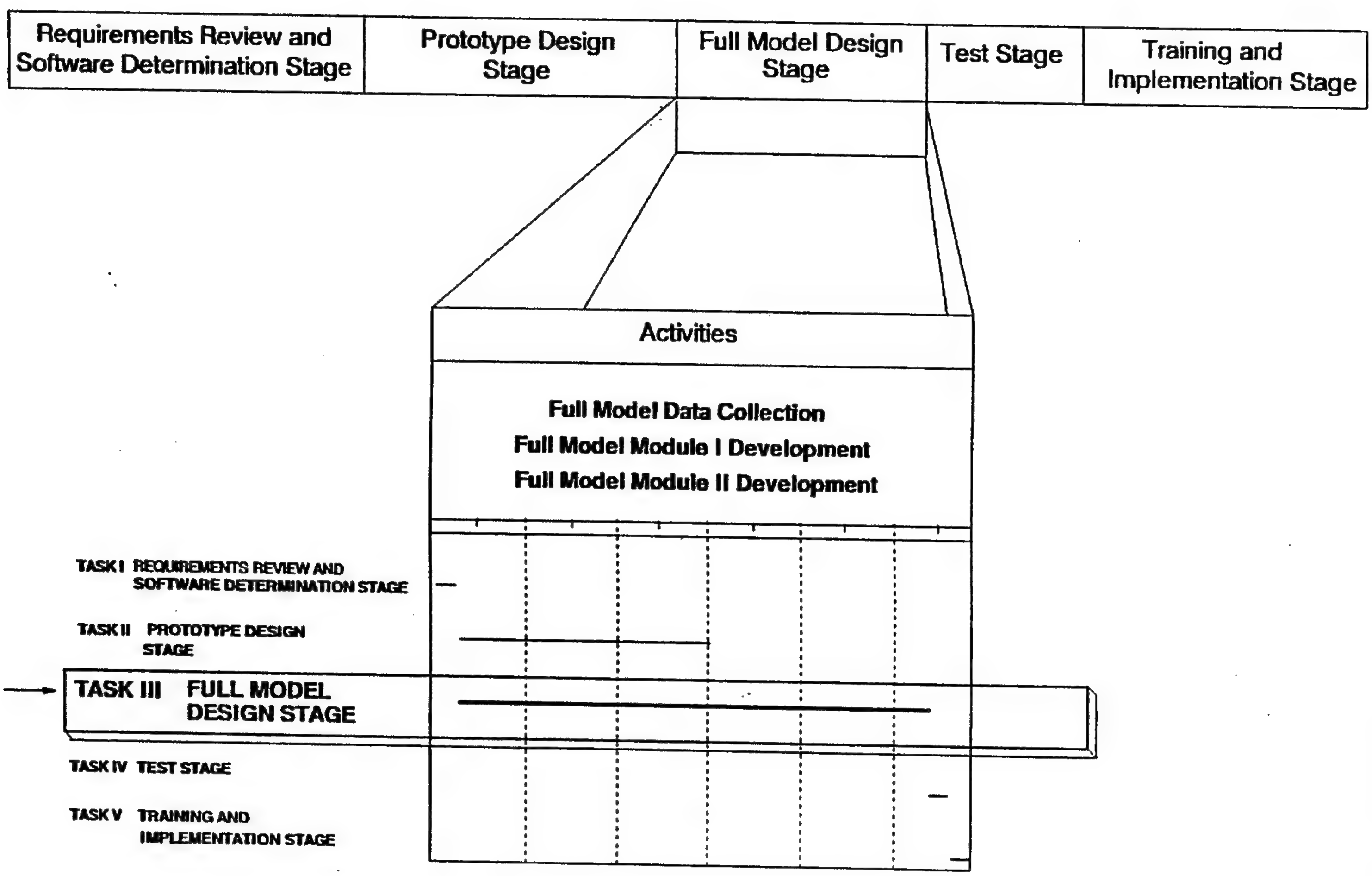

Figure 2.5 Full Model Development Stage.

2.7 TEST STAGE

As mentioned earlier, the contractor will develop alternative technologies or pieces of equipment to demonstrate, test, and verify the model. These alternatives will be designed to test each capability's performance in the overall effectiveness of the Soldier System. The contractor will also test the sensitivity capabilities of the model to ensure the proper information is being derived. This stage is not designed to test the commercial software package, but the application developed on it.

2.8 TRAINING AND IMPLEMENTATION STAGE

The contractor will provide training to the user in the form of a tutorial document, and seminar which will demonstrate the capabilities and functions of operating the MCDA.

2.9 DOCUMENTATION

The contractor will produce a users guide which will include all key functions in operating the SSA MCDA. At completion the contractor will also deliver the manuals for the software package used in developing the SSA MCDA.

2.10 DELIVERABLES

The contractor will deliver to the government at the end of the model development:

- Fully functioning SSA MCDA installed on Natick hardware.
- Software used in the development of the model
- SSA MCDA users manual.
- MCDA design document outlining the program structure for future modifications to the model.
- Final SSA MCDA report documenting the development process of the model.

SECTION 3
CONCLUSIONS AND RECOMMENDATIONS

3.1 CONCLUSIONS

- Data retrieval is the major obstacle in the development of the SSA MCDA and will be the most time intensive task.
- A MADM methodology is best suited for the SSA MCDA.
- Utility theory should be used to quantify the Soldier System capabilities.
- The SIPE results should serve as the kernel of the SSA MCDA

3.2 RECOMMENDATIONS

- That Natick implement the SSA MCDA development plan.

This document reports research undertaken at the U.S. Army Soldier Systems Command, Natick Research, Development and Engineering Center and has been assigned No. NRDEC/TR-96/030 in the series of reports approved for publication.

APPENDIX A

SCIENCE APPLICATIONS TECHNICAL 1992 REPORT:

SSA LITERATURE SEARCH AND MARKET SURVEY REPORT

SOLDIER SYSTEM ARCHITECTURE

(SSA)

LITERATURE SEARCH AND MARKET SURVEY

TECHNICAL REPORT

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11 AUGUST 1992

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"The views and/or findings contained in this report are those of the authors and should not be construed as an official Department of the Army position, policy, or decision unless so designated by other documentation. "

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SOLDIER SYSTEM ARCHITECTURE
(SSA)
LITERATURE SEARCH AND MARKET SURVEY

SECTION 1
INTRODUCTION

1.0 BACKGROUND

Army programs concerned with the development and fielding of new equipment must support increasingly complex mission requirements and allow the soldier to successfully operate in increasingly hostile and sophisticated threat environments. Resources are highly constrained and are under constant scrutiny. Consequently, new programs and equipment must be cost-effective and must be capable of apriori demonstration of the fact. 'The individual soldier is already burdened with an excessive load. New equipment must replace existing equipment to reduce the soldier's load while maintaining or increasing his mission capabilities.

At present, there are a variety of computer modeling tools designed to assist the military analyst but none that address the needs of the Soldier as a System. However, these models are cumbersome to use and require a high degree of operator expertise, significant investment in input parameter preparation, and skilled analysts to interpret the results. Furthermore, they do not allow the addition of novel threats, and they do not consider changes in performance or capabilities resulting from changes in technology. Also, these models are not structured to consider risk, cost, and time to field for any anticipated changes in the input parameters. In essence, they are not structured to answer resource allocation questions.

To both resolve the equipment questions and optimize the development of the Soldier System, a Soldier System Architecture (SSA) multi-criteria decision aid (MCDA) is being developed. The SSA will consist of two modules. The first will quantify the changes to soldier capabilities from changes in the items, equipment, or technologies available to the soldier system. The second will assist in the determination of optimal resource allocations based on the trade-offs between costs, technological risks, and benefits; as restricted by the availability of funds, time, and personnel resources.

The current Natick multi-criteria decision aid effort, the Soldier System Hierarchical Effectiveness Model has been addressing the immediate, time-sensitive needs of Soldier System initiatives, but Natick believes that an independent assessment of the over-all technical approach

is needed to ensure that the final SSA product will meet the more expansive needs of the future. Therefore, a literature search of appropriate methodologies and market survey of applicable software products which utilize the methodologies discovered in the literature search was conducted.

1.1 PURPOSE

The development and implementation of the SSA have been defined as a multi-phase effort. Phase One, which is currently being implemented, calls for:

- A detailed literature search to identify past or present DoD, Academia and/or Industry methodologies that factor performance and resource allocation into final output,
- A market survey of applicable software products implementing such methodologies,
- A User Conference to solicit inputs and needs for such a MCDA from potential users,
- A detailed plan for the development of the SSA MCDA based on the results of the earlier efforts in the phase.

This report provides the results of the SSA MCDA literature search and market survey.

SECTION 2
TECHNICAL APPROACH

2.1 OVERALL APPROACH

As mentioned earlier, the SSA MCDA will consist of two modules. The first will quantify the changes to soldier capabilities. The second will assist in the determination of optimal resource allocations based on trade-offs. Therefore, the technical approach for the literature search and the market survey addressed the requirements of both modules.

2.2 APPROACH FOR METHODOLOGY LITERATURE SEARCH

SAIC initiated an extensive literature search of available methodologies that can perform multi-criterion decision analysis or otherwise improve the decision making process for large, complex problems under uncertain conditions . The technical database search employed the services of the SAIC Corporate Technical Resource Acquisition Center (CTRAC) to access several information collection and retrieval services. The services accessed included the National Technical Information Center (NTIC), Defense Technical Information Center (DTIC), INSPEC, COMPENDEX, and MATHSCI.

Identification of applicable MCDAs was initiated by accessing studies or analytical efforts that contained key words or terms used in multi-criteria analysis. Terms that were searched included the following:

- Operations research or analysis
- Management analysis or science
- Decision analysis or science
- Optimization models
- Multi-criteria decision aids
- Linear programming
- Utility theory
- Influence diagrams

A large number of reports were identified and the abstracts were reviewed by the SAIC team. The most promising studies and reports were ordered for further assessment. The process focused on those studies that entailed human performance or human factors, that sought optimal resource allocation (especially for R&D or manpower issues), and that provided methods for quantifying issues that are difficult to evaluate (large problem scope and size, policy decisions with unclear criteria/values, decisions involving future risk or uncertainty, etc.).

In addition to the CTRAC search, SAIC analysts conducted an extensive library search for useful decision analysis material. These included the Army Library at the Pentagon, the Defense Systems Management College Library at Fort Belvoir, George Mason University Library, George Washington University Library, and the Library of Congress, Washington, DC.

SAIC analysts investigated other agencies as well, to determine if any recent studies or investigations were applicable. Inquiries were made to the Naval Postgraduate School's Operations Research and Administrative Sciences Departments. A search was also conducted on current military wargaming and military simulation models that could help in quantifying improvements in soldier systems.

Inquires were made to the Defense Logistics Studies Information Exchange (DLSIE) and to the general studies and the models data bases. A tailored search using the DLSIE Descriptor List was conducted. In addition to some of the key terms used in earlier searches, more focus was obtained by using such descriptive terms as: combat effectiveness, command and control, survivability, performance evaluation, and infantry related to military personnel and human factors. The *Studies and Models Bibliographies* provided by DLSIE were reviewed by SAIC, but few of the cited references were appropriate for further investigation.

SAIC attended The Institute on Management Sciences and Operations Research Society of America (TIMS/ORSA) Joint National Conference to glean the latest developments in the academic and commercial applications of MCDAs.

2.3 APPROACH FOR MCDA MARKET SURVEY

The approach of the market survey was to locate existing software through researching applicable government and academic technical databases and various academic journals. The NTIC, DTIC, INSPEC, COMPENDEX, and MATHSCI databases were queried for software packages which had been developed utilizing any of the methodologies identified by the literature search. The search also concentrated on packages which were designed to solve resource allocation optimization problems. Some of the academic journals researched for application MCDA, in addition to the database searches, are listed below:

- *OR/MS TODAY*
- *DECISION SCIENCES*
- *OPTIMIZATION*
- *OPSEARCH*
- *DECISION SUPPORT SYSTEMS*

- *JOURNAL OF OPERATIONS RESEARCH SOCIETY*
- *OPERATIONS RESEARCH*
- *MANAGEMENT SCIENCE*

Through TIMS/ORSA Joint National Conference, SAIC also gathered information on the latest developments in academic and commercial MCDA software packages.

Through the first phase of the market survey a wide range of commercial software packages capable of solving complex multi-criteria decision problems were found. An assessment of the applicability of the software packages to the SSA MCDA described in Section 3 was then conducted.

SECTION 3
MODULE ONE LITERATURE SEARCH AND MARKET SURVEY RESULTS

3.1 MODULE ONE LITERATURE SEARCH RESULTS

A key challenge in developing the first module of the SSA MCDA is the quantification of the soldier's capabilities into useful measures of effectiveness (MOEs). SAIC conducted a literature search of methodologies capable of measuring the soldier's capabilities.

3.1.1 OVERALL MODULE ONE LITERATURE SEARCH RESULTS

As a result of the search process, several pertinent Government reports were identified. Included were:

- *Using Influence Diagrams*
- *Influence Diagrams: Automated Analysis with Dynamic Programming*

Both reports were written for the US Air Force Institute of Technology. For example, the *Using Influence Diagrams* study gives a tutorial on how to effectively use influence diagrams in gathering expert opinion and knowledge of a system. Influence Diagrams are a recent development in the decision science arena and are discussed in detail in the following subsection.

SAIC gathered data from the Crew System Ergonomics Information Analysis Center (CSERIAC) located at Wright-Patterson AFB, Ohio. This joint program between Government and academia sponsors research that is useful for investigating many aspects of man-machine interface, although the primary thrust of CSER is air crews, not individual soldiers.

3.1.2 DETAILED MODULE ONE LITERATURE SEARCH RESULTS

Through the literature review, three useful techniques were found: Utility Theory, Influence Diagrams, and Decision Conferences.

Utility Theory provides a means of capturing subjective expressions of worth in quantifiable form. While Utility Theory cannot eliminate the effect of this subjectivity, it at least attempts to minimize its effect. Utility Theory arises from the classical precepts of rationality, preferential maximization, and predictability of aggregate phenomena. Utility Theory is prescriptive, concerned with the choice among pre-specified alternatives according to the principle of maximization of subjective expected utility. This theory is drawn from statistical

decision theory, mathematical economics, and econometrics. Utility Theory is driven by utility functions. A utility function corresponds to a specific category or characteristic of a system and allows for changes within a category without losing any relative worth. Utility Theory is a relatively old technique for quantifying capabilities and desires; yet, because of its flexibility it is still one of the most effective and widely used methods today.

Influence Diagrams are a relatively new technique for gathering expert opinion and knowledge. Influence Diagrams were developed as a Bayesian computer-aided modeling tool by Howard and Matheson. An algorithm for solving Bayesian decision analysis problems through Influence Diagram manipulations was constructed by Shachter. Influence Diagrams are a graphical approach to assessing system dynamics and interrelationships while attempting to capture expert opinion on preference between attributes. The Air Force is using Influence Diagrams and developing PC based decision analysis tools based on this methodology. There is potential benefit for this type of approach in assessing the interrelationships of the SSA MCDA capabilities. The SSA problem in its definition is inherently interdependent. For example, the ultimate utility of both micro-climate cooling and the soldier computer are constrained by the rate of development of power (battery) technologies. Influence Diagrams offer a methodological approach for the subject matter expert to systematically analyze the interdependencies between the SSA attributes.

One of the recent outgrowths of the Delphi Method of group decision making is Decision Conference. The Department of Energy recently conducted a Decision Conference to rank the research projects currently under consideration for funding and found the exercise quite useful. Although the SSA would require a much higher degree of resolution, the Decision Conference approach offers an alternative for deriving weights and preferences between capabilities and attributes. However, being a derivation of the Delphi method it is very time and user intensive requiring multiple meetings and a high degree of dedication and effort on the part of the participants. This method becomes less effective if the group cannot meet several times over a period of a few months.

3.2 MODULE ONE SOFTWARE MARKET SURVEY RESULTS

The following subsections outline the results of the market survey for applicable government, commercial and academic software to quantify the soldier's capabilities for the first module of the SSA MCDA.

3.2.1 GOVERNMENT MODULE ONE SOFTWARE

SAIC found three Government efforts which offer some useful information to the SSA problem of Quantifying Capabilities.

The first applicable model is Performa. The report, *Performa, A Personal Influence Diagram System for Decision Analysis,* describes the design and implementation of a software system used for analyzing and solving influence diagrams for the decision analysis community at the US Air Force Institute of Technology. The paper describes a review of Software Systems for Decision Analysis that evaluated commercial software packages to gain information in the design of the current effort. The packages evaluated were DAVID for the Macintosh, SMLTREE, and ARORIST. The review indicated that there was limited capability, at that time-1987, to analyze an influence diagram formulation with a computer. Also, from the broad spectrum of personal and mainframe computers available, there was no system flexible enough for unusual problems. The paper does offer an excellent tutorial of using influence diagrams and illustrates how well an influence diagram can serve as both a formal problem description that can be analyzed with a computer and an informal representation that can be easily understood by those that are not acquainted with mathematical formulation.

The report *Measuring the Benefits of MPT R&D* provides guidance on the evaluation of MPT research projects that are difficult to quantify. Four techniques were compared in this study: utility analysis, production functions, cost benefit analysis, and decision analysis. Utility analysis was found to be most useful in measuring benefits of selection tests or other intervention devices in which productivity of the worker can be measured before and after the intervention. Decision analysis was found most useful in rank ordering R&D projects, rather than measuring the benefit of R&D projects. Cost Benefit analysis was found to have practical application to the R&D project problem in comparing alternatives. The author concludes that these techniques used not alone but in concert, would improve the ability to make R&D selections. The author also concluded that research into these areas, in light of budgetary constraints, will allow the research community to make positive, supportable statements about the value of its products.

Influence Diagrams: Automated Analysis with Dynamic Programming, describes the development of a user friendly package for processing influence diagrams with Dynamic Programming. Some examples of a Dynamic Program are yearly budget allocations, program scheduling, and minimum path planning. The goal of dynamic programming is to select the sequence of decisions which yield the maximum expected value for the problem. This package was also developed to assist the decision analysis community at the US Air Force Institute of

Technology. The package, called AFids, was to replace the PERFORMA software referenced earlier, and offer enhanced user-friendliness. The report offers some insights into the types of problems best suited for influence diagrams with dynamic programming. The author concludes that AFids handled dynamic programming problems with large amounts of uncertainty very well. However, when AFids was asked to do the job of a linear program in answering whether or not to pay for R&D on a weapon, it was not as efficient. The large number of simplifications and discretizations necessary to fit the problem into an influence diagram formulation shed considerable doubt on the validity of the solution even before the solution was attempted. The author concludes that the AFids program is a powerful tool for a wide variety of problems, but alone does not lend itself to resource allocation problems. This effort illustrates that influence diagrams alone do not offer the complete solution for the SSA MCDA problem. However, it shows the areas where this type of approach could be used with great effectiveness, quantifying areas of uncertainty.

3.2.2 COMMERCIAL/ACADEMIC MODULE ONE SOFTWARE

Some of the commercial software available for quantifying capabilities include INDIA, DPL, and DAVID. Detailed discussion of these packages is included in the following table. Each entry in the table presents the package type (influence diagrams or utility theory, how suitable the package is in meeting the current SSA module one requirements, and a comment column with a brief description of the package's capabilities.

FIGURE A-1: COMMERCIAL SOFTWARE PACKAGES AND CAPABILITIES

NAME:	TYPE: INFLUENCE DIAGRAMS/ UTILITY THEORY	SUITABILITY: LOW MED HIGH	COMMENTS:
DAVID	INFLUENCE DIAGRAMS		User interface, graphics based influence diagram program. However, this package is only available for the Macintosh format.
DPL	INFLUENCE DIAGRAMS		DPL is a decision tree and influence diagram package. Virtually unlimited in problem size, DPL offers a system which takes advantage of some of the virtues of each approach, eg. influence diagrams are best at precisely describing probabilistic relationships, and decision trees are best at clearly describing the decision sequence.
INDIA	INFLUENCE DIAGRAMS		One of the most popular influence diagram packages, INDIA offers an excellent user interface in a windows environment. However, solving influence diagrams is its only capability, making it ineffective in satisfying the total requirements of the SSA MCDA.
LOGICAL DECISION	UTILITY THEORY		Logical Decision, a multi-measure decision analysis tool, is an excellent small trade-off analysis software package. Some of its key features include self generated utility functions within the program and extensive sensitivity analysis. However, it is constrained by the number of attributes it can handle and therefore receives a medium rating.

SECTION 4
MODULE TWO LITERATURE SEARCH AND MARKET SURVEY RESULTS

4.1 MODULE TWO LITERATURE SEARCH RESULTS

The literature search for methodologies for the second module of the SSA MCDA are presented in the following subsections. The first subsection gives an initial look at the results while citing some specific Government efforts or Academic projects of interest. The second subsection offers a detailed discussion of the methodologies which are most suitable for accomplishing the SSA MCDA goals, along with their benefits and drawbacks.

4.1.1 OVERALL MODULE TWO LITERATURE SEARCH RESULTS

As a result of the review process, several pertinent Government reports were identified. They include:

- *An Extension of the Analytic Hierarchy Process for Industrial R&D Project Selection and Resource Allocation*

- *Measuring the Benefits of Manpower, Personnel and Training (MPT) Research and Development*

- *A Prototype Meta-Language and Automated Translator for Decision Analysis Problem Formulation*

- *A Personal Computer Based DSS for Computer-Family Selection*

Several of the reports were theses prepared at the US Air Force Institute of Technology (AFIT). For example, the *Prototype Meta-Language* study developed software which can translate problems into a format used by decision analysis software. This may become significant for the SSA MCDA if the availability of accurate data becomes a concern.

The Naval Postgraduate School (NPG) provided information on current programs, but most were not a match with the current effort. These conversations led to contacts with U.S. Army Training and Doctrine Command (TRADOC) Analysis Command (TRAC) -Monterey personnel. They provided additional ideas on the directions that are currently being pursued in

MCDA and evaluations of the soldier as a system. They also helped to identify those models currently being used in areas related to SSA, such as JANUS, HARDMAN, and others.

The literature search of current military wargaming and military simulation models yielded several models and software products that have been developed within the DoD, primarily by the US Air Force Institute of Technology (AFIT, the Defense Systems Management College (DSMC), and other agencies.

The chart below summarizes many of the Government agencies and organizations and databases which provided information on studies, models, and other resources that were employed in the investigation:

	STUDIES	MODELS	OTHER
National Technical Information Center (NTIC) and Defense Technical Information Center (DTIC)	x	x	
Army Library	x		Defense Systems
DSMC	x	x	
AFIT	x	x	Current R&A
Crew Station Ergonomics Information Analysis Center(CSERIAC)			Future Analysis
Naval Postgraduate School		x	Current Research & Analysis
TRAC-Monterey	x		Current Research & Analysis
Def. Logistics Studies Info. Exchange	x	x	

4.1.2 DETAILED MODULE TWO LITERATURE SEARCH RESULTS

From these initial results the problems of Multiple Criteria Decision Analysis can be broadly classified into two categories: Multiple Attribute Decision Making (MADM), and Multiple Objective Decision Making (MODM). In practice MADM is used for selection or evaluation, whereas MODM is used for designing a system. MODM is not used for problems in which the alternatives are predetermined. The thrust of this approach is to design the "best" system by considering the various interactions within the design constraints which best satisfy

the objectives. A MODM possesses a set of quantifiable objectives, a set of well defined constraints, and a process of obtaining some trade-off information between the objectives. A MADM has a number of predetermined alternatives. These alternatives have associated levels of merit (which may not necessarily be quantifiable) from which a final decision is made. The final selection is made by inter- and intra-attribute comparisons. These comparisons may involve explicit or implicit trade-offs.

Linear Programming is an example of a MODM. It reaches an optimal solution by satisfying its objective based on a set of constraints. LP has been used extensively in solving resource allocation problems. By setting a constraint of X dollars which needs to satisfy the objective Y, a LP algorithm will optimally allocate Z resources. A LP approach would be effective in designing the optimal Soldier System and generating sensitivity analysis for "what if" analysis. However, most LP packages require extensive programming to be user friendly and require a skilled analyst for effective manipulation and update.

Two examples of MADM techniques which hold the most promise for the SSA MCDA are Decision Trees and Trade-off Analysis.

Decision Trees offer an optimal solution by deriving the best choice from a series of decisions. A Decision Tree is a graphical representation of the decisions, uncertainties and values of a problem, and a framework for numerical evaluation. Based on the principals of dynamic programming, the solution of a Decision Tree starts at the tree endpoints and by computing the expected value at each uncertainty node and the optimal value at each decision node. The suboptimal choices at each decision node are dropped and the roll back continues until the first node of the tree is reached. The optimal solution is derived by the choices selected at each decision node that maximize the value of the objective function. Being a graphical representation of the problem, Decision Trees makes the linkage between decisions and the state of information obvious.

Trade-off Analysis encompasses a wide range of techniques used to assist in making decisions under uncertainty. These techniques offer the decision maker a ranking between alternatives and optimal solution. These techniques differ from the two previous approaches in that these are most useful for mixed qualitative/quantitative problems. Consequently they do not offer as much sensitivity and are not as robust. However, many times they act as an excellent first phase in "mapping out" the hierarchy or structure of a system. Trade-off Analysis techniques include the mature Analytical Hierarchy Process (AHP) being employed in the Soldier System Hierarchal Effectiveness Model; which is developing a prototype representation

of the Soldier System as a weighted hierarchy of solider capabilities. Other examples of the technique include the Simple Additive Weighting method (SAW), The Technique for Order Reference by Similarity to Ideal Solution (TOPSIS), and Elimination et Choice Translating Reality (ELECTRE).

4.2 MCDA SOFTWARE MARKET SURVEY RESULTS

There are a wide range of computer modeling tools designed to assist the military analyst. Many of these models are not appropriate for the SSA problem. They are either too large in scope for the Soldier System, cumbersome to use, require a high degree of operator expertise, significant investment in input parameter preparation, or demand skilled analyst interpretation of the results. Some members of the user community are currently using relatively small, low level MCDAS. While less cumbersome, they are not satisfactory for the SSA due to the constraints in problem size inherent in these packages.

The results of the MCDA market survey are presented in the following subsections which is divided into two segments. The first segment discusses the information found on applicable Government MCDA efforts. The second segment presents the applicable academic/commercial software packages with some detailed information in a tabular format.

4.2.1 GOVERNMENT MODULE TWO SOFTWARE

The information found through the market survey yielded no software package developed or currently being developed by the Government that would have significant application to the SSA MCDA. However, many Government efforts were found that pertain to ranking non-quantitative criteria for applications such as source selection boards, prioritization of R&D efforts, and for making manpower/personnel/training (MPT). There are two government efforts which do lend the most useful information to the SSA problem.

First, is the Decision Support System for Resource Allocation Model, produced by the Operations Research and Economic Analysis Office of the Defense Logistics Agency. The model report, dated 1989, was developed to assist decision makers in allocating constrained resource dollars. Two optimization models were created, A Stock Fund Allocation Model and a Commitment Dollar Allocation Model (CDAM). The CDAM was used for integration into the prototype DSS as it was designed to answer real time questions of what items to buy and how much of each should be bought. This report, and others found during the market survey,

illustrate that the majority of resource allocation MCDAs have been used for monetary or supply models. Little has been done on the scope of the SSA MCDA.

The second applicable effort is the Use of *Computer-Aided Decision Support Systems for Complex Source Selection Decisions,* a thesis from the Air Force Institute of Technology. In this thesis the author develops a DSS for source selection using an AHP approach. In his conclusions the author states that his AHP approach to DSS was ineffective in enhancing the decision maker's ability to make "better" decisions. The author concludes that one reason for this ineffectiveness might be because the problem itself was too simple and did not model the complexity of a real world situation. However, some positive effects did occur which are of interest to the SSA MCDA. There was a positive correlation between the use of the DSS and how "easy" the decision-maker found the process. A positive correlation was also observed for the confidence of the decision-maker in his own decision and with his understanding of the decision making process when the DSS was used. The increase in confidence and problem understanding from any MCDA approach could be an invaluable asset in formulating the complex interrelationships of the SSA MCDA model.

4.2.2 COMMERCIAL/ACADEMIC MODULE TWO SOFTWARE

The following table presents the software packages found in the market survey for the SSA MCDA. Some of the entries from the module one market survey are included here because of their ability to meet both module's requirements. Each entry in the table presents the package type (linear programming, decision tree, or trade-off), how suitable the package is in meeting the current SSA MCDA requirements, and a comment column explaining this suitability rating. This suitability rating was based on the following factors:

- Adaptability - Defined as how easily the package could be tailored to the specific requirements of the SSA MCDA. If the package required a complex graphical user interface (GUI) to make it useful or if its own existing GUI was impractical for the SSA requirements, then it was given a lower rating.
- Size/Capability - Defined as how large a problem can the package model. Many of the LP packages have a virtually unlimited problem size, whereas some of the trade-off analysis packages had a severe problem size restriction. Since the SSA MCDA is envisioned as a larger model, the size/capability of a program becomes a critical issue.

All the information in the form of brochures or marketing packages received during this market survey has been provided to the Government under separate cover.

FIGURE A-2: COMMERCIAL SOFTWARE PACKAGES:
ADAPTABILITY AND SIZE/CAPABILITY

NAME:	TYPE: LP/DECISION TREE/ TRADE-OFF	SUITABILITY: LOW MED HIGH	COMMENTS:
CPLEX	LINEAR PROGRAMMING	ADAPTABILITY SIZE/CAPACITY OVERALL	Extremely fast, stable, and reliable optimizer designed to handle large and difficult problems. Uses a simple user interface for interactive or batch mode operation. Would require extensive development of a GUI to be effective for the SSA MCDA.
DPL	DECISION TREE	ADAPTABILITY SIZE/CAPACITY OVERALL	DPL is a decision tree and influence diagram package. Virtually unlimited in problem size DPL offers a system which takes advantage of some of the virtues of each approach, eg. influence diagrams are best at precisely describing probabilistic relationships, and decision trees are best at clearly describing the decision sequence.
EXPERT CHOICE	TRADE-OFF	ADAPTABILITY SIZE/CAPACITY OVERALL	A very effective and mature decision software package, Expert Choice uses the AHP methodology to give rankings between alternatives. However, it is constrained by the number of attributes it can handle.
GAMS	LINEAR PROGRAMMING	ADAPTABILITY SIZE/CAPACITY OVERALL	This software is not a LP package, but an optimization language. It offers flexibility in designing the problem, but would require extensive GUIs to make it an effective tool for the SSA MCDA.

FIGURE A-2: COMMERCIAL SOFTWARE PACKAGES: ADAPTABILITY AND SIZE/CAPABILITY (CONT'D)

NAME:	TYPE: LP/DECISION TREE/ TRADE-OFF	SUITABILITY: LOW MED HIGH	COMMENTS:
GINO	LINEAR PROGRAMMING	ADAPTABILITY SIZE/CAPACITY OVERALL	Designed to solve problems and sets of simultaneous linear and nonlinear equations and inequalities. Gino is a modeling tool which utilizes other optimizers such as LINDO to solve the problem. The package requires extensive GUIs to make it useful for the SSA MCDA.
INDIA	INFLUENCE DIAGRAMS	ADAPTABILITY SIZE/CAPACITY OVERALL	One of the most popular influence diagram packages, INDIA offers an excellent user interface in a windows environment. However, solving influence diagrams is its only capability, making it ineffective in satisfying the total requirements of the SSA MCDA.
LINDO	LINEAR PROGRAMMING	ADAPTABILITY SIZE/CAPACITY OVERALL	One of the most widely used LP packages LINDO offers speed and ease of use for solving linear, non-linear, and quadratic programming problems. However, it has a poor user interface and requires an analyst with a high degree of skill.
LINGO	LINEAR PROGRAMMING	ADAPTABILITY SIZE/CAPACITY OVERALL	LINGO's linear, nonlinear, and integer solvers and interactive modeling environment make it a comprehensive tool. However it may be too complex for the SSA MCDA, with capabilities and attributes which would go unused in the SSA MCDA.

FIGURE A-2: COMMERCIAL SOFTWARE PACKAGES: ADAPTABILITY AND SIZE/CAPABILITY (CONT'D)

NAME:	TYPE: LP/DECISION TREE/ TRADE-OFF	SUITABILITY: LOW MED HIGH	COMMENTS:
LOGICAL DECISION	TRADE-OFF	ADAPTABILITY SIZE/CAPACITY OVERALL	Logical Decision, a multi-measure decision analysis tool, is an excellent small trade-off analysis software package. Some of its key features include self generated utility functions within the program and extensive sensitivity analysis. However, it is constrained by the number of attributes it can handle and therefore receives a medium rating.
LP88	LINEAR PROGRAMMING	ADAPTABILITY SIZE/CAPACITY OVERALL	LP88 is a stand alone LP package with a menu-driven user interface. However the package would need additional GUIs to make it useful for the SSA MCDA.
MATHPRO	LINEAR PROGRAMMING	ADAPTABILITY SIZE/CAPACITY OVERALL	Mathpro is mathematical programming support model. It includes a Dialog Manager, Database Manager, and Model Manager. It supports optimizers such as XPRESS and CPlex. However, it has a complex user interface and requires an analyst with a high degree of skill.

FIGURE A-2: COMMERCIAL SOFTWARE PACKAGES:
ADAPTABILITY AND SIZE/CAPABILITY (CONT'D)

NAME:	TYPE: LP/DECISION TREE/ TRADE-OFF	SUITABILITY: LOW MED HIGH	COMMENTS:
$MATRIX_X$	LINEAR PROGRAMMING	ADAPTABILITY SIZE/CAPACITY OVERALL	$MATRIX_X$ is a comprehensive inter system analysis tool and consists of an optimization module, simulation module, control design module and digital signal processing module. Its optimization module is only a small portion of what this software was designed to do. It would require extensive programming to make this program useful for the SSA MCDA, and the program itself would be under-utilized since most of the applications are not applicable to the SSA MCDA requirements.
MPL	LINEAR PROGRAMMING	ADAPTABILITY SIZE/CAPACITY OVERALL	MPL is an advanced modeling language capable of solving all types of LP models. It has an integrated model development environment that features pull-down menus, pop-up windows, a built-in model editor and a view utility for the generated input files. It is one of the more advanced user interfaces available within LP software, and therefore receives a medium rating. Once again however, the analyst must be skilled to operate this package successfully.

FIGURE A-2: COMMERCIAL SOFTWARE PACKAGES:
ADAPTABILITY AND SIZE/CAPABILITY (CONT'D)

NAME:	TYPE: LP/DECISION TREE/ TRADE-OFF	SUITABILITY: LOW MED HIGH	COMMENTS:
MPS III/pc	LINEAR PROGRAMMING	ADAPTABILITY SIZE/CAPACITY OVERALL	MPS's fully integrated model manager simplifies complex modeling tasks such as recursion and scenario management. It has a poor user interface and requires an analyst with a high degree of skill. However, it is one of the fastest and most capable packages on the market.
OSL	LINEAR PROGRAMMING	ADAPTABILITY SIZE/CAPACITY OVERALL	OSL is an optimizer designed for application development. Applications are portable across supported platforms which are varied. OSL is specifically designed to be used in a tailored applications environment. Requires extensive design knowledge by the analyst, however, this approach enables OSL to be tailored directly to the requirements of the SSA MCDA.
PC-PROG	LINEAR PROGRAMMING	ADAPTABILITY SIZE/CAPACITY OVERALL	PC-PROG works in batch and interactive mode, including full-screen editor, model builder, MPS format support, Quadratic programming, and MIP. Fast and user friendly compared to most LP packages. Tailoring to the SSA MCDA would be difficult.
SCIOCONIC	LINEAR PROGRAMMING	ADAPTABILITY SIZE/CAPACITY OVERALL	SCIOCONIC is an algorithmically advanced MP package which solves linear, integer, and nonlinear MP problems. It does have a very rudimentary user interface and would require a very skilled analyst for manipulation.

FIGURE A-2: COMMERCIAL SOFTWARE PACKAGES:
ADAPTABILITY AND SIZE/CAPABILITY (CONT'D)

NAME:	TYPE: LP/DECISION TREE/ TRADE-OFF	SUITABILITY: LOW MED HIGH	COMMENTS:
SIMULAB	LINEAR PROGRAMMING	ADAPTABILITY SIZE/CAPACITY OVERALL	SIMULAB is a very large system for modeling and analyzing dynamic systems, including linear, non linear, continuous, discrete, and hybrid model types. Very user friendly, but too much power for the SSA. The optimizer is only a small part of the total power of this system. Therefore it would be ineffective in satisfying the requirements of the SSA MCDA.
SMLTREE	DECISION TREE	ADAPTABILITY SIZE/CAPACITY OVERALL	SMLTREE is a decision tree analysis program which enables the construction of large decision models by which complex choices and decisions can be analyzed. It does have a very rudimentary user interface which would be difficult to tailor to the SSA MCDA.
STORM	LINEAR PROGRAMMING	ADAPTABILITY SIZE/CAPACITY OVERALL	The strength of STORM lies mainly in the ease and speed with which users can construct fairly large models in an interactive manner with the help of its unique spreadsheet-like Data Editor and therefore has gained wide acceptance as a teaching tool. However, the other components of STORM, such as the PERT module, make it an ineffective choice for the SSA MCDA.

FIGURE A-2: COMMERCIAL SOFTWARE PACKAGES:
ADAPTABILITY AND SIZE/CAPABILITY (CONT'D)

NAME:	TYPE: LP/DECISION TREE/ TRADE-OFF	SUITABILITY: LOW MED HIGH	COMMENTS:
SUPERTREE	DECISION TREE	ADAPTABILITY SIZE/CAPACITY OVERALL	Supertree is a classic decision tree system. It evolved from earlier work done at SRI, and has been used in various forms since 1980. Supertree has several limitations on model size and complexity. Supertree's models are limited to eight chance variables, if each has three states and each affects the value function. Supertree also has limitations on the amount of information that it can retain and show at any one time, partly due to memory management, and partly due to its tree format and policy display.
TOPSIS	TRADE-OFF	ADAPTABILITY SIZE/CAPACITY OVERALL	TOPSIS is an algorithm used in Multiple Attribute Decision Making. Developed by Ching-Lai Hwang and Kwangsun Yoon in 1980, TOPSIS is based on the concept that the selected alternative, in a graphical linear program sense, should have the shortest graphical distance from the best ideal solution and the farthest graphical distance from the worst-ideal solution. TOPSIS is limited by the size of problem it is able to solve and could not satisfy the SSA MCDA requirements.

FIGURE A-2: COMMERCIAL SOFTWARE PACKAGES:
ADAPTABILITY AND SIZE/CAPABILITY (CONT'D)

NAME:	TYPE: LP/DECISION TREE/ TRADE-OFF	SUITABILITY: LOW MED HIGH	COMMENTS:
TURBO-SIMPLEX	LINEAR PROGRAMMING	ADAPTABILITY SIZE/CAPACITY OVERALL	Designed for efficient development of LP models. Its integrated environments features pull-down menus, pop-up windows, built-in model editor, and an output viewer. The input manager allows long variable names, arithmetic like fraction/parenthesis, named data constants and include files. It is one of the more advanced user interfaces available within LP software, and therefore receives a medium rating. Once again however, the analyst must be skilled to operate this package successfully.
VIG/VIMDA	TRADE-OFF	ADAPTABILITY SIZE/CAPACITY OVERALL	Has a poor user interface and requires an analyst who has a high degree of skill.
WHAT'S BEST	LINEAR PROGRAMMING	ADAPTABILITY SIZE/CAPACITY OVERALL	What's Best lets your build linear, integer, and nonlinear model in your favorite spreadsheet. Models are easy to understand using standard spreadsheet equations; powerful enough to handle large models. A useful tool for providing models to clients.

FIGURE A-2: COMMERCIAL SOFTWARE PACKAGES: ADAPTABILITY AND SIZE/CAPABILITY (CONT'D)

NAME:	TYPE: LP/DECISION TREE/ TRADE-OFF	SUITABILITY: LOW MED HIGH	COMMENTS:
XA LPS	LINEAR PROGRAMMING	ADAPTABILITY SIZE/CAPACITY OVERALL	XA linear and mixed 0/1 integer solver provides smooth spreadsheet integration to both 1-2-3 and Excel. Subroutine library allows you to solve directly into your C or Fortran Problems. Because this is only a solver it might be an option for a LP approach since the GUI could be tailored directly to the SSA MCDA without cumbersome problems that tailoring more complex packages might encounter.
XPRESS-MP	LINEAR PROGRAMMING	ADAPTABILITY SIZE/CAPACITY OVERALL	XPRESS-MP is a high performance LP and MIP optimizer offering large model size capacity, reliability, portability, compatibility with spreadsheets and relational DBMs and easy integration into user developed applications such as the SSA MCDA.

SECTION 5
CONCLUSION AND RECOMMENDATIONS

The conclusions and recommendations of the literature search and market survey for the SSA MCDA are as follows:

Conclusions:

- The type of resource allocation problems facing the SSA MCDA development are not new. Extensive research has been done on this type of problem, with numerous applications developed for systems (financial, equipment), but none with a human as the central focus.
- Although there are past and current Government studies on crew and unit performance, the individual soldier has not been studied at the level of detail of the SSA MCDA.
- There are three applicable methodologies which meet the requirements of the first module of the SSA MCDA:

  - Influence Diagrams
  - Utility Theory
  - Decision Conference

- There are three applicable methodologies which meet the requirements of the second module of the SSA MCDA:

  - Linear Programming
  - Decision Trees
  - Trade-off Analyses

- There is a wide variety of software available, utilizing the methodologies listed above, for the SSA MCDA. These software packages vary in the type of user interface they use. Some are user friendly with advanced GUI's others have rudimentary text file editors.
- There is a clear inverse relationship between the power of a software package and its ease of use. A determination must be made between the trade-off of power/capability and ease of use.
- Locating and transforming useful data needed for developing accurate measures of effectiveness in the first module of the SSA MCDA will be difficult.

Recommendations:

- That one of the methodologies be used to develop the SSA MCDA, either independently or in concert with one or more other methodologies.
- That a final selection of the methodology and software package should be made during the detailed planning phase of the SSA MCDA based on this assessment and additional user input.
- That the SSA MCDA encapsulate the current Soldier Integrated Protection Ensemble (SIPE) effort's methodology.

APPENDIX B

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